Characterizing Cosmic Dawn with the Low-Band EDGES Instrument

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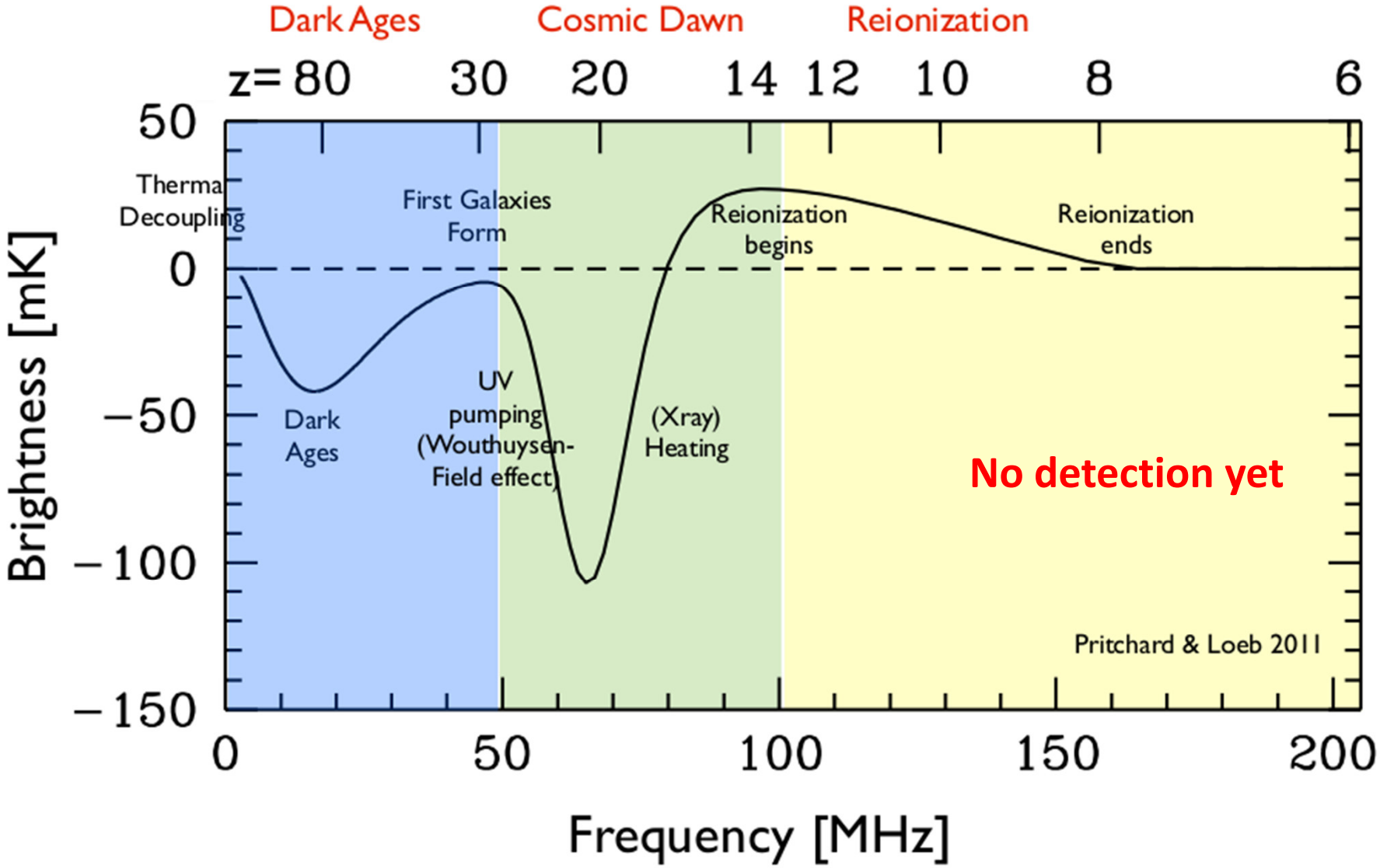
MIT HAYSTACK OBSERVATORY

Science


Dark Ages
Cosmic Dawn
Reionization
z= 80
30
20
14
12
10
8
6
50
0
−50
−100
−150
Brightness [mK]
Therma
Decoupling
First Galaxies
Form
Reionization
begins
Reionization
ends
Dark
Ages
UV
pumping
(Wouthuysen-
Field effect)
(Xray)
Heating
No detection yet
Pritchard & Loeb 2011
0
50
100
150
200
Frequency [MHz]

EDGES

(& Cosmic Dawn)

Experiment to Detect the Global EoR Signature

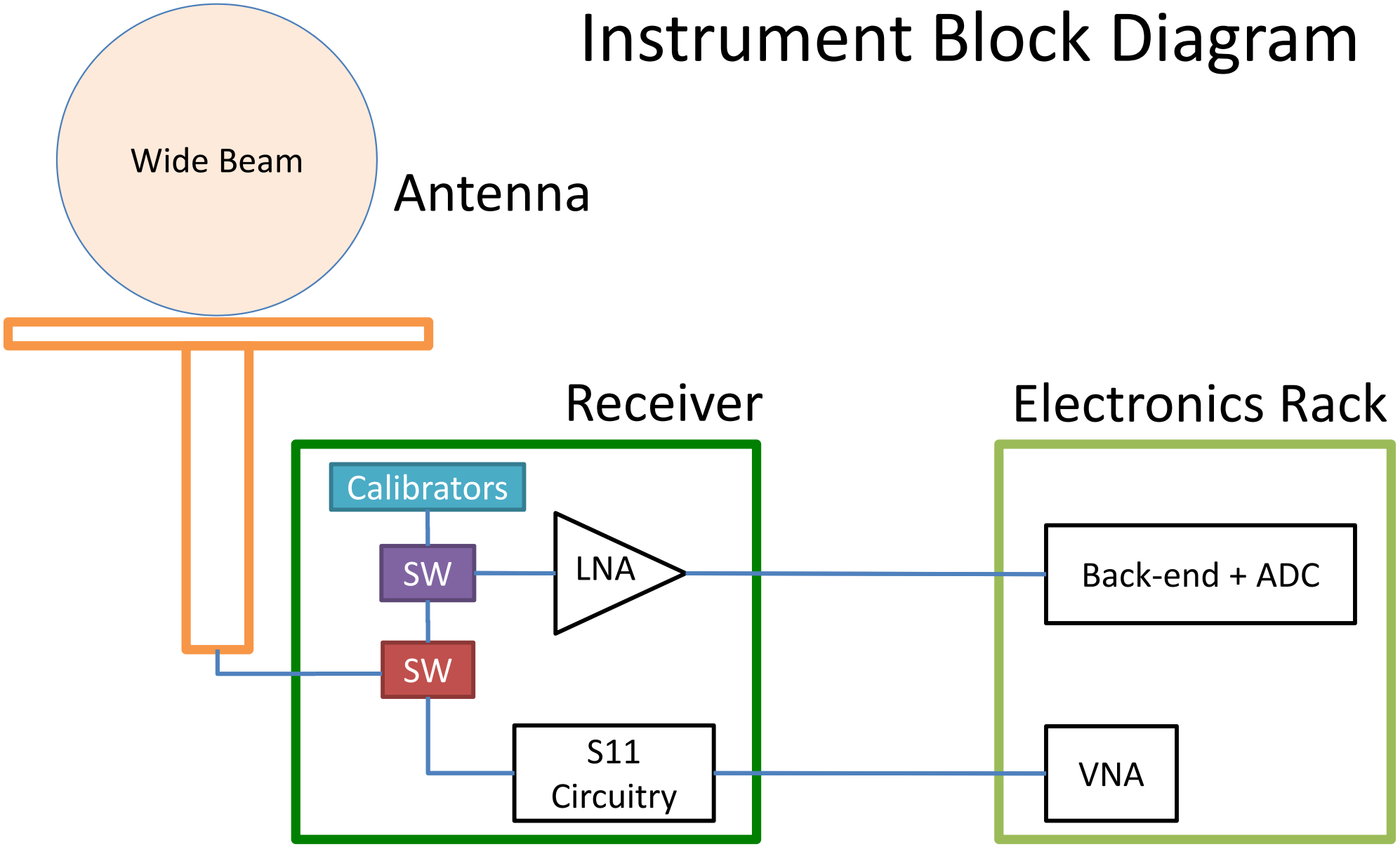
- EDGES-I (2008 - 2012), Bowman & Rogers (2010) (Nature Journal)
- EDGES-II (2012 - Present)
- Starting 2015, **TWO** independent instruments:

Low-Band and **High-Band**

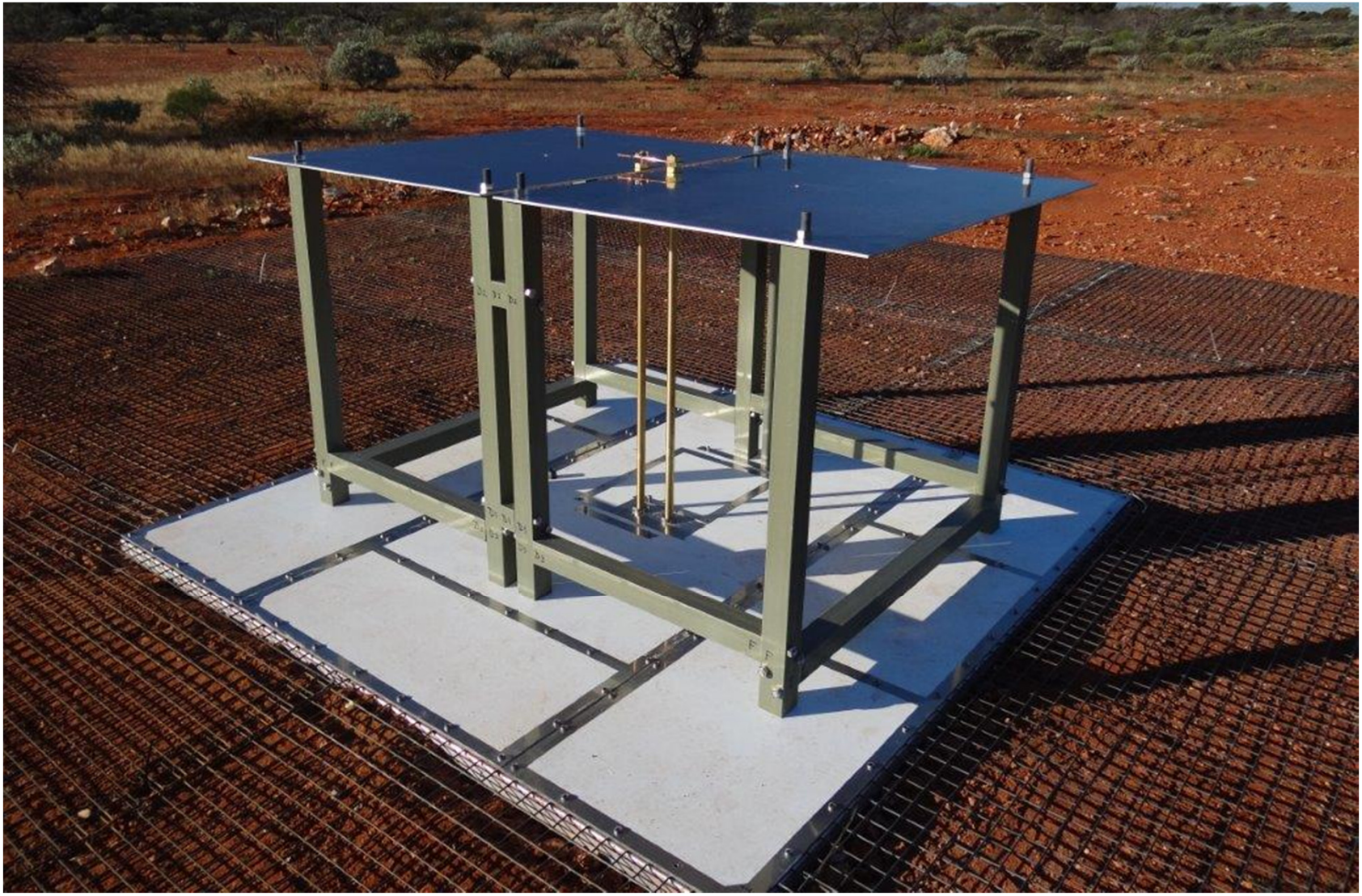
50-100 MHz **100-200 MHz**

Radio-Quiet Location: Murchison, WA

Instrument Block Diagram

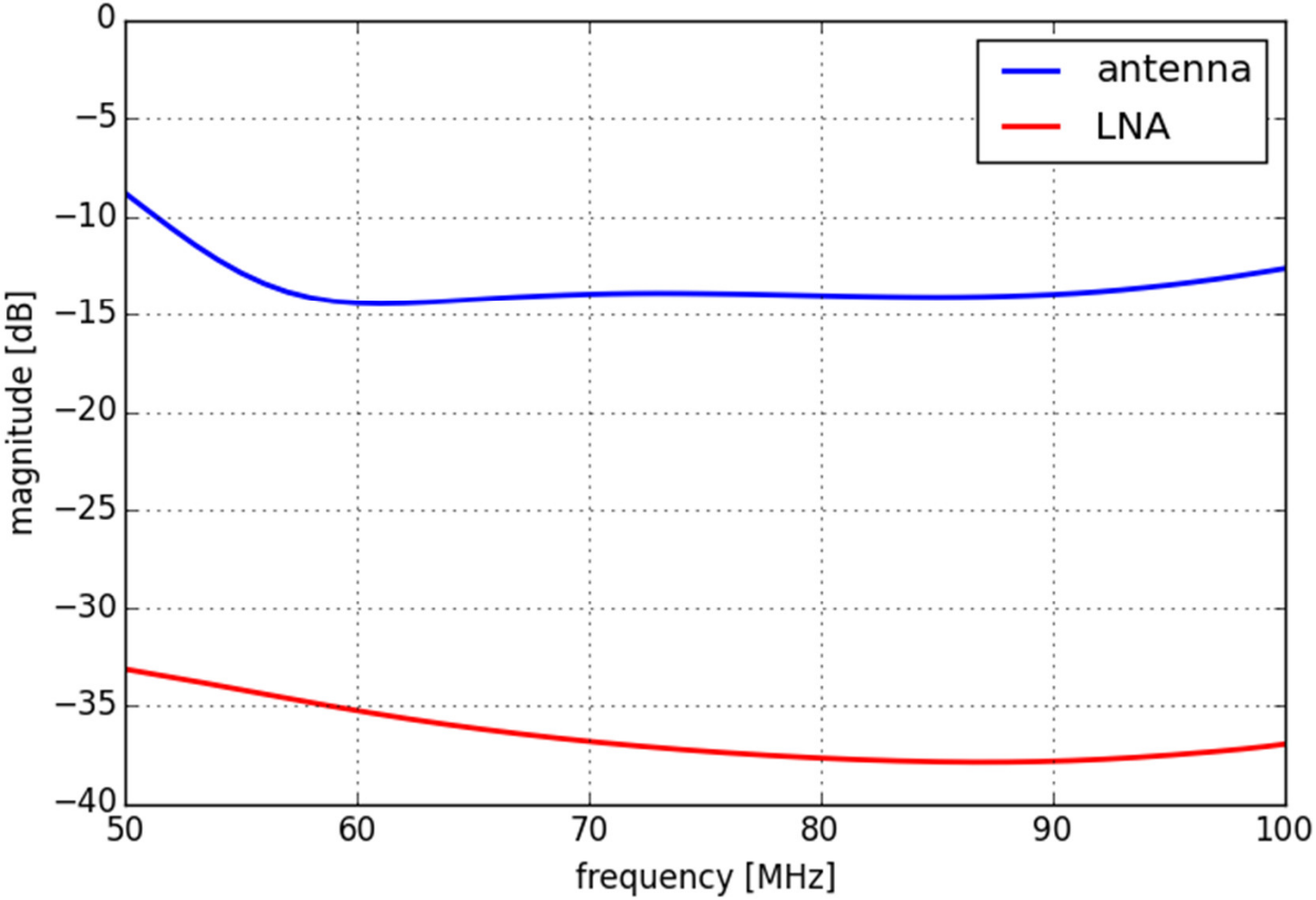


EDGES **Low-Band** 2015

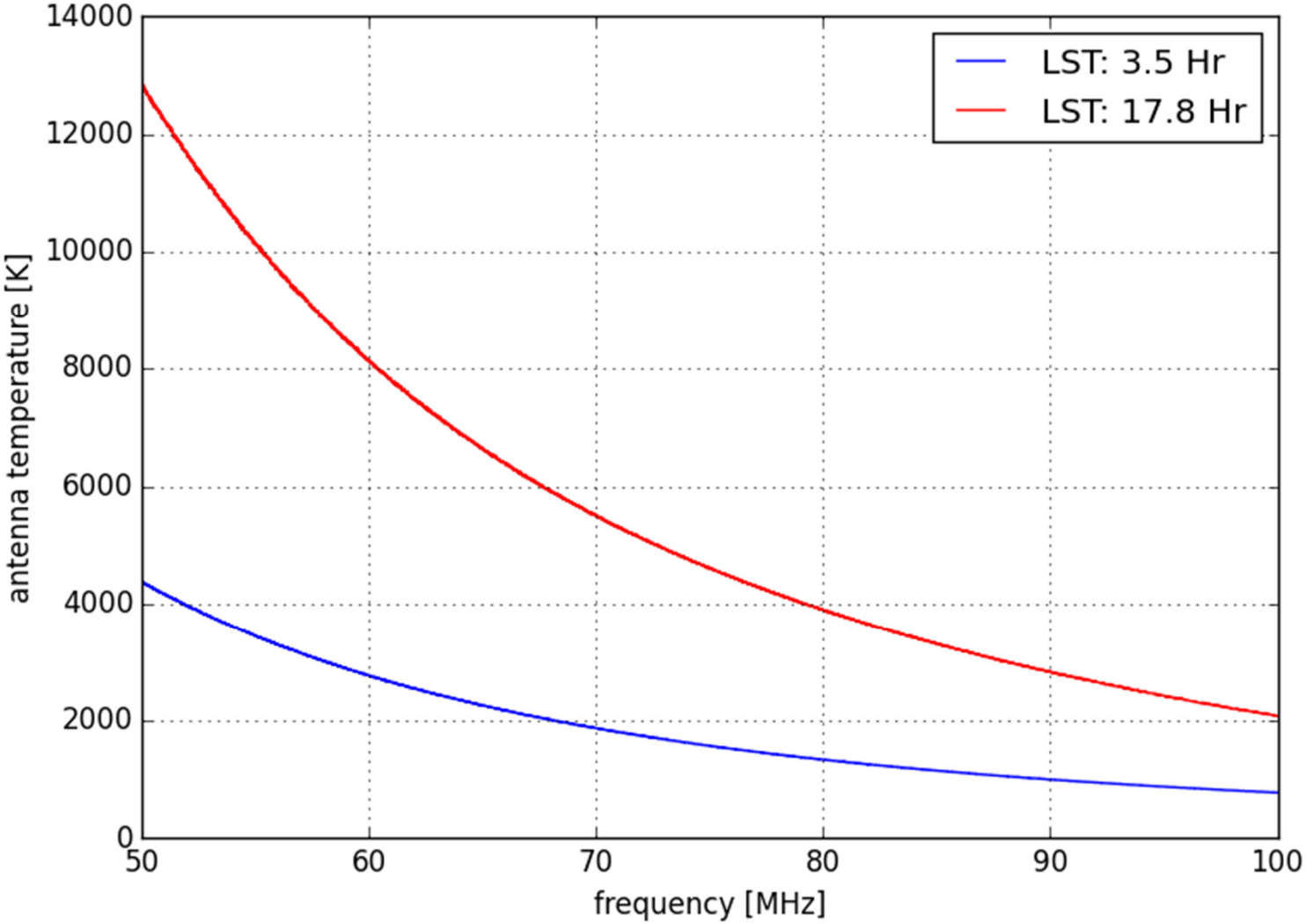


EDGES **Low-Band** 2015

Low-Band Reflection Coefficients



Calibrated Antenna Temperature



Models

Regular Polynomial:

$$\hat{T}_{\text{ant}} = \sum_{i=0}^{N} a_i \nu^i$$

"EDGES" Polynomial:

$$\hat{T}_{\text{ant}} = \nu^{-2.5} \sum_{i=0}^{N} a_i \nu^i$$

Log-Log Polynomial:

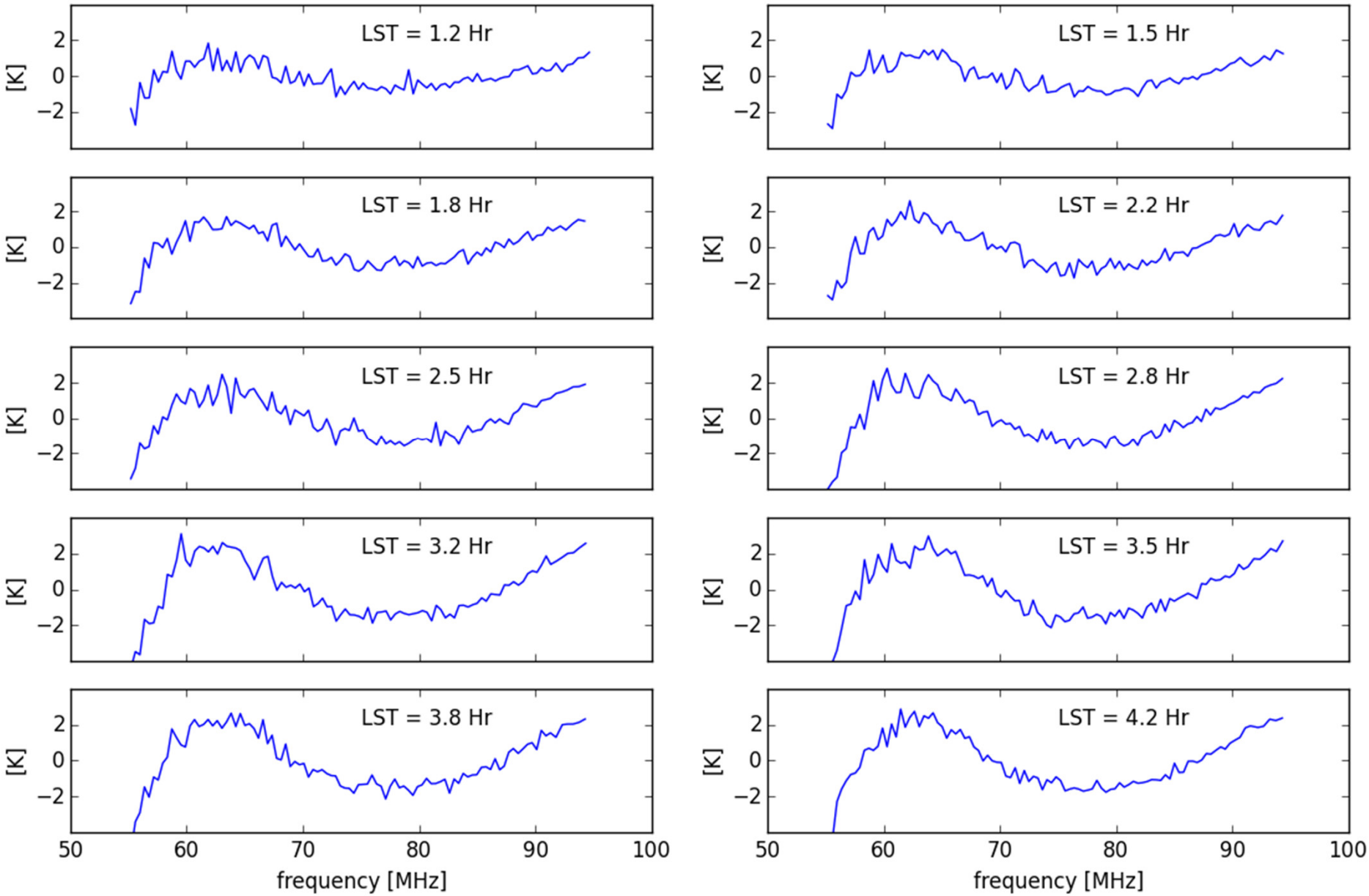
$$log(\hat{T}_{\text{ant}}) = \sum_{i=0}^{N} a_i \cdot [log(\nu)]^i$$

"Physical" Polynomial:

3 parameters for sky foreground
2 parameters for ionospheric absorption/emission

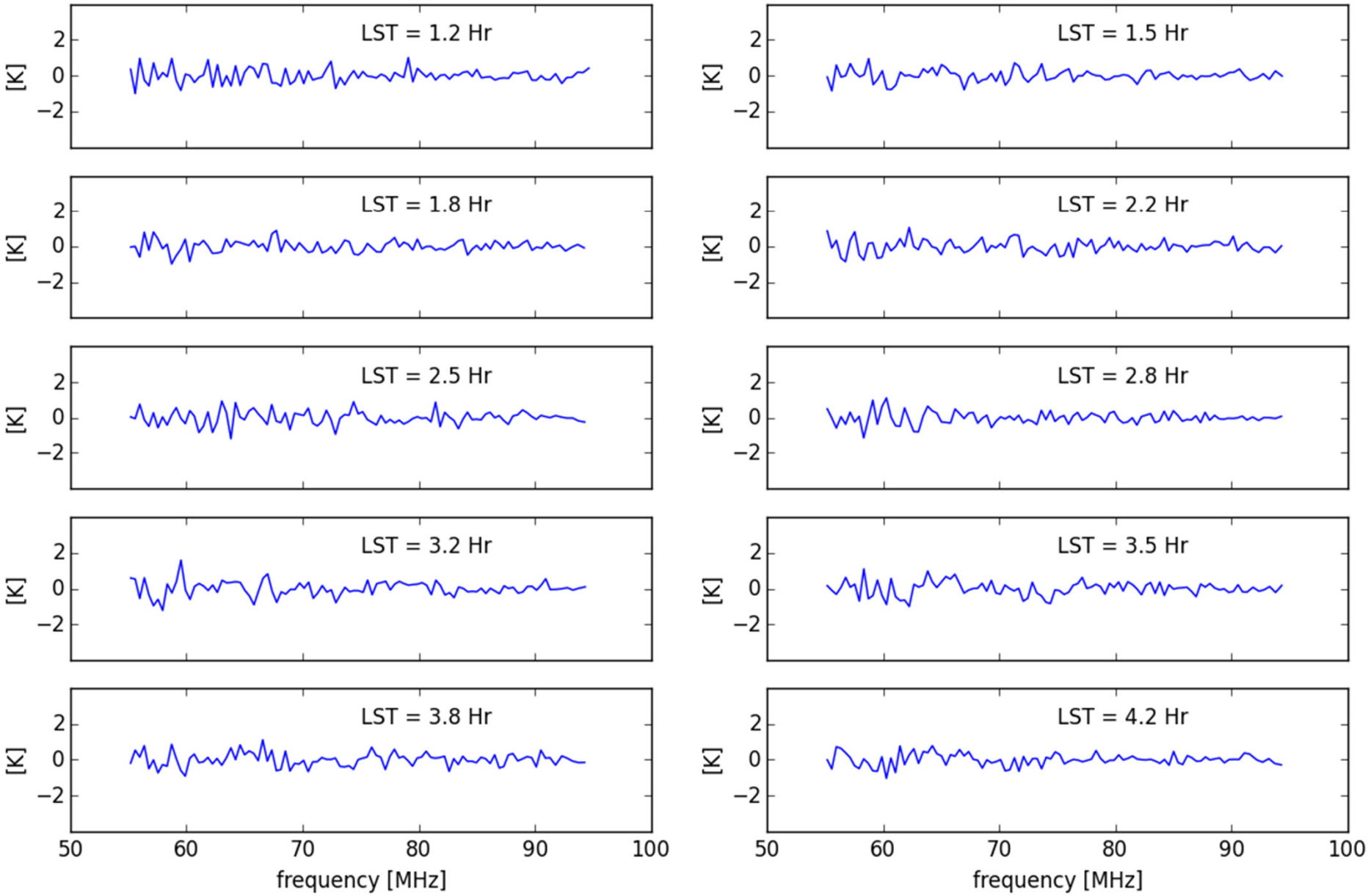
Sample: Removing “EDGES” Polynomial with 3 Terms

5-day average at each 20-minute LST bin. For presentation purposes only.



Sample: Removing “EDGES” Polynomial with 5 Terms

5-day average at each 20-minute LST bin. For presentation purposes only. RMS ~ 350 mK.



Status of Analysis

Amount of data with blade antennas to date:

- **High Band**: 120 Days
- **Low Band**: 50 Days

After data selection and averaging, RMS residuals:

- **High Band**: ~ 30 mK
- **Low Band**: ~ 100 mK
- After removing 5 model terms
- Not limited by noise

Status of Analysis

- We have achieved residuals of **same order of magnitude** as expected **cosmological signal**.
- Conducting a thorough set of **validation** tests, **cross-checks**, sensitivity **analyses**.
- As **more data** are gathered, the understanding of limits **will improve**.
- In parallel, we are preparing to **rule out extreme** cosmological **scenarios**.
- Preparing to **rule out EoR durations** in the range $\mathbf{0.5 < \Delta z < 1.0}$ for certain ranges of reference redshifts. Factor of $\sim$ **10 improvement** wrt results from 2010.

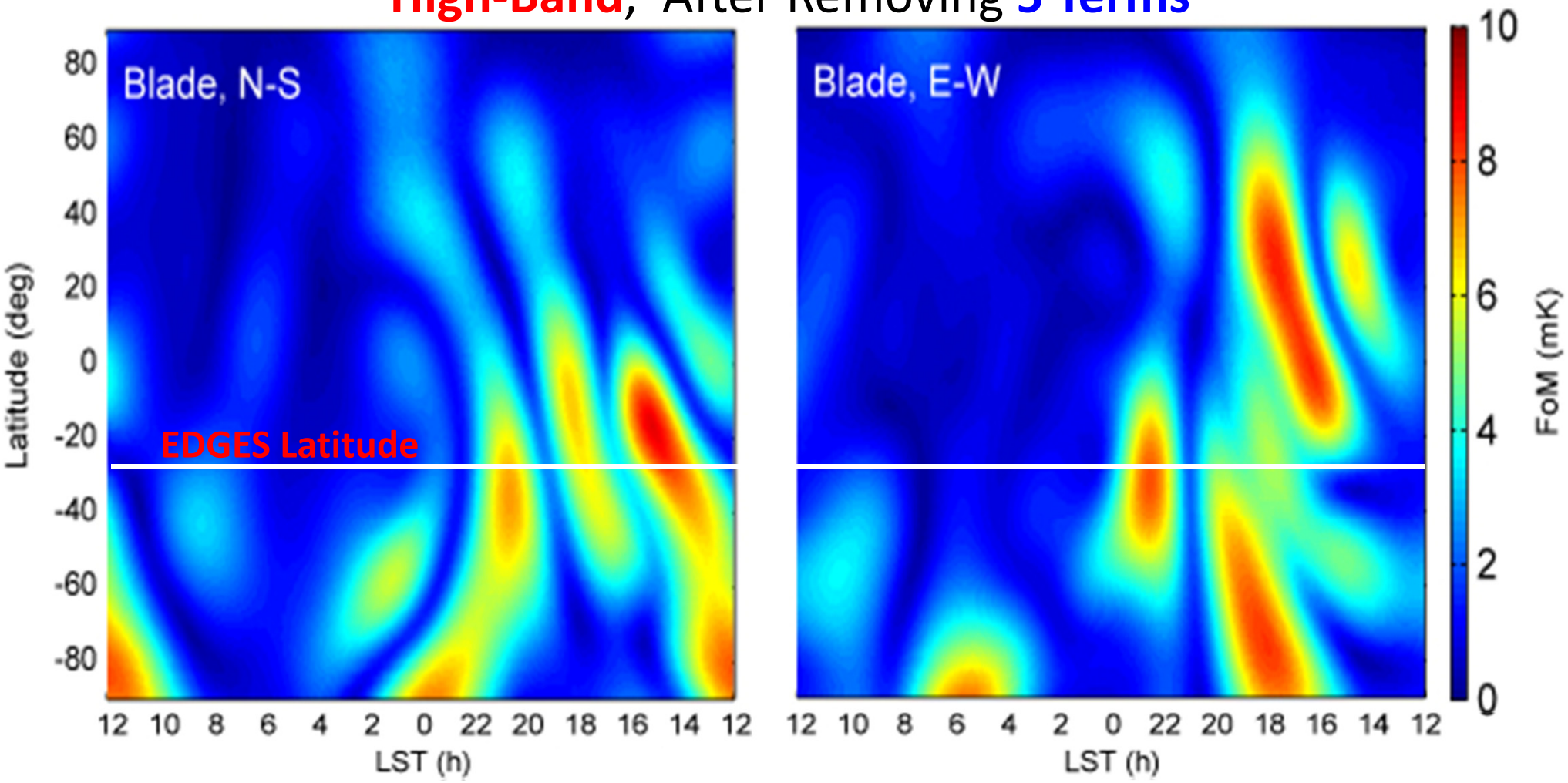
Summary

- **Two** EDGES instruments.
- Conducting continuous **sky measurements.**
- Data model requires $\geq$ **5 terms** due to imperfect knowledge of **Foregrounds / Ionosphere / Antenna Beam / Antenna Losses / Calibration Systematics.**
- **Current residuals** of **same order of magnitude** as **cosmological signal.**
- Stay tuned for **papers** in the **next** few **months**.

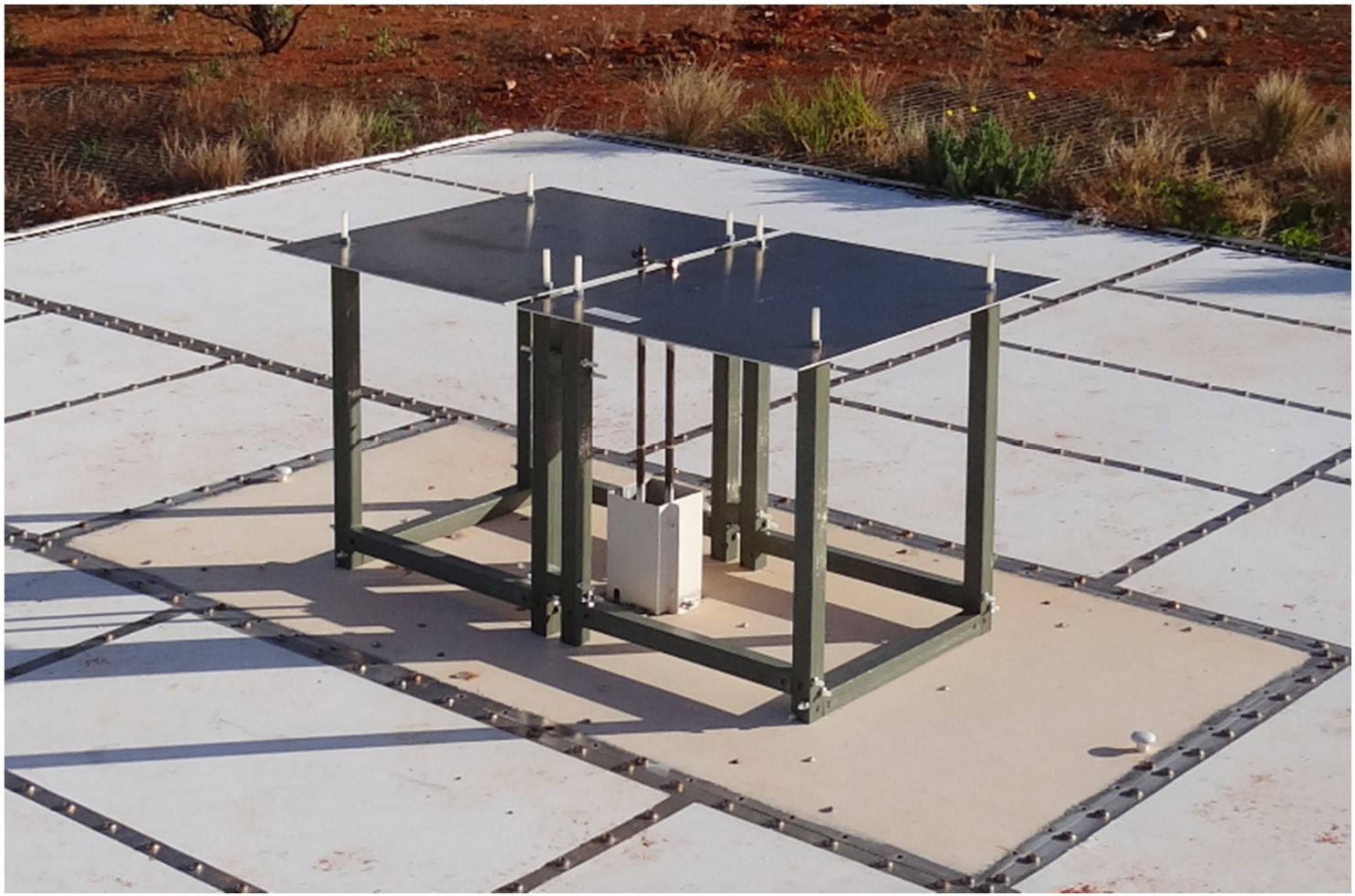
Backup Slides

New "Blade" Antenna Performance

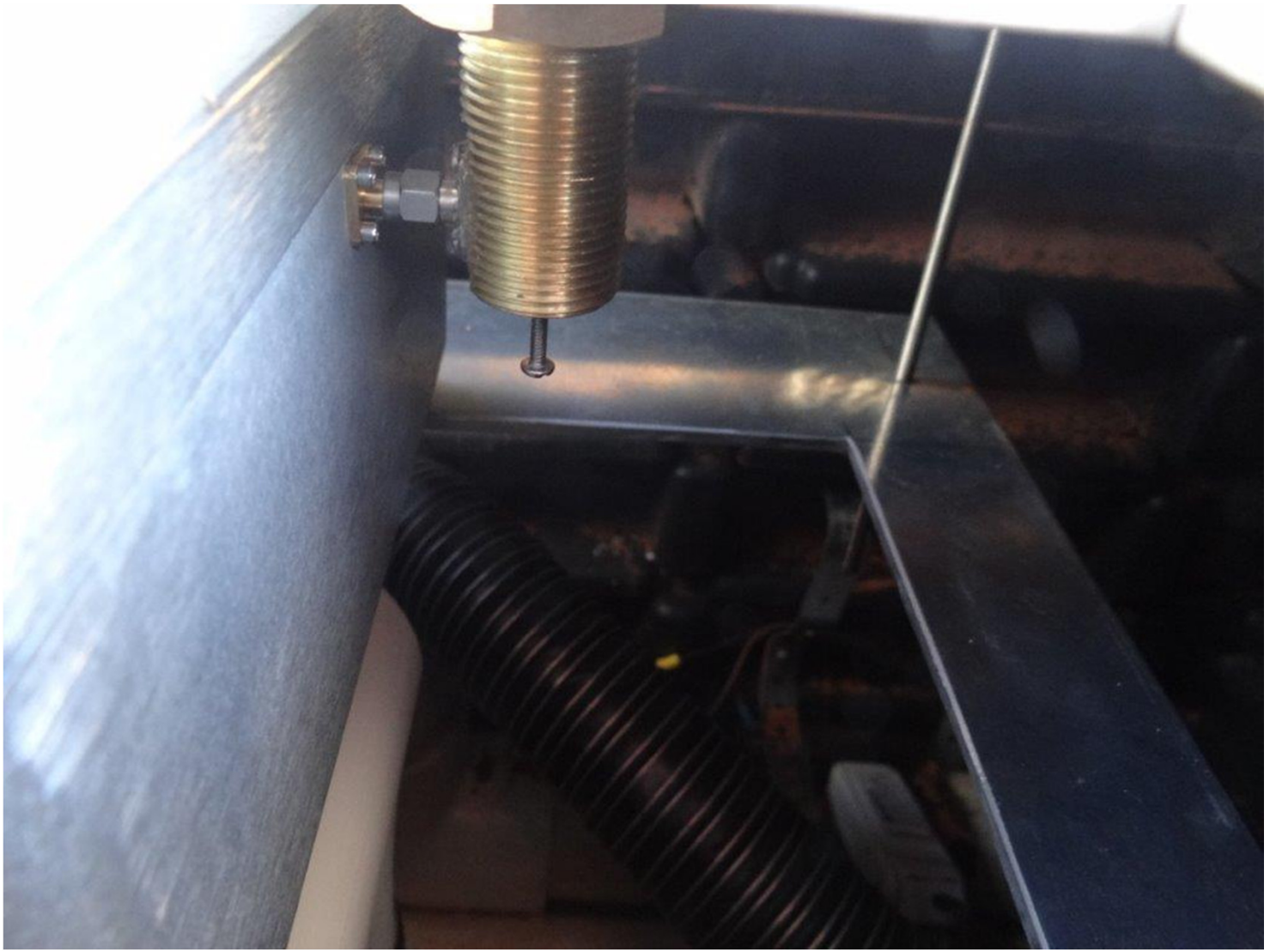
High-Band, After Removing 5 Terms



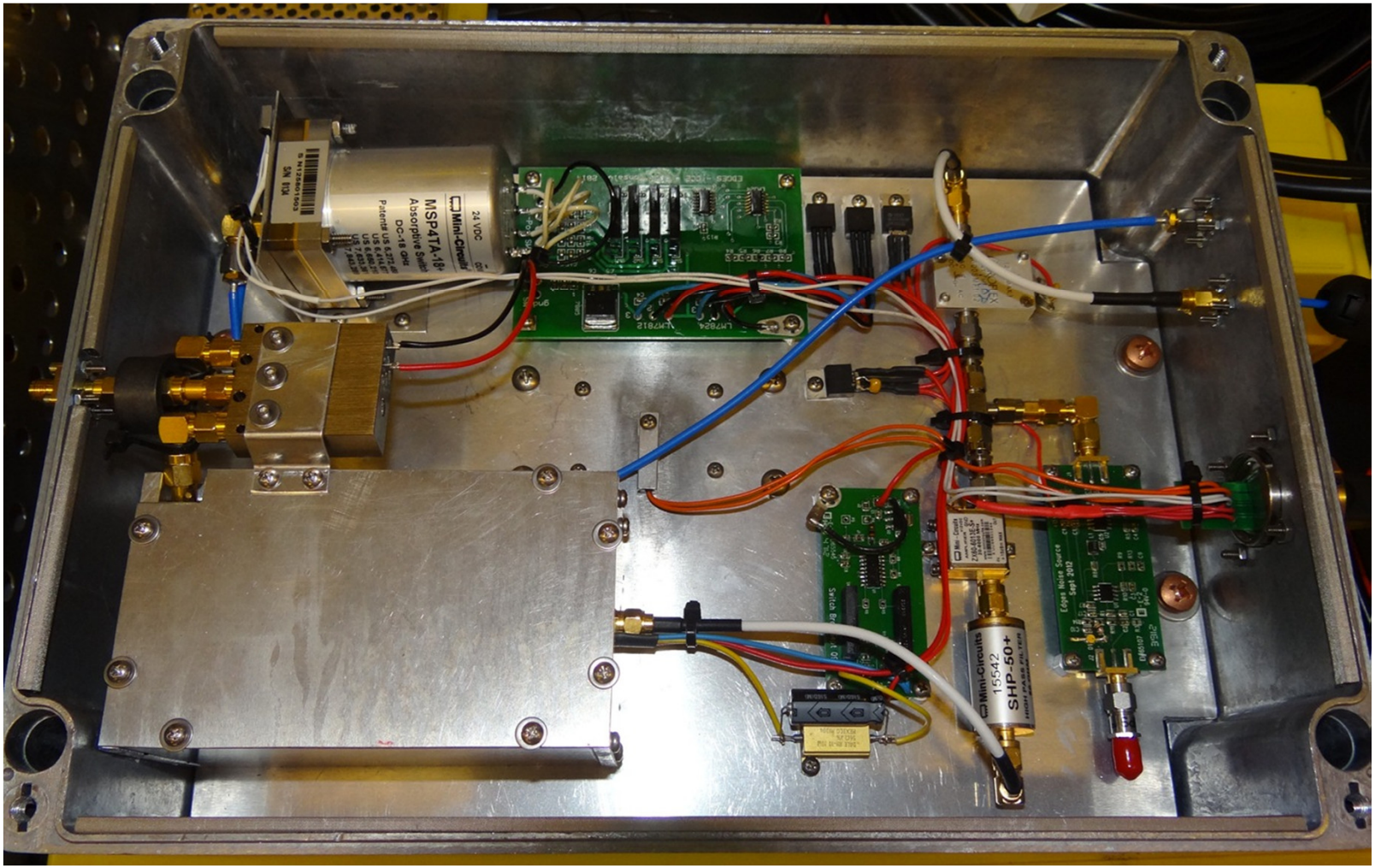
EDGES **High-Band** 2015



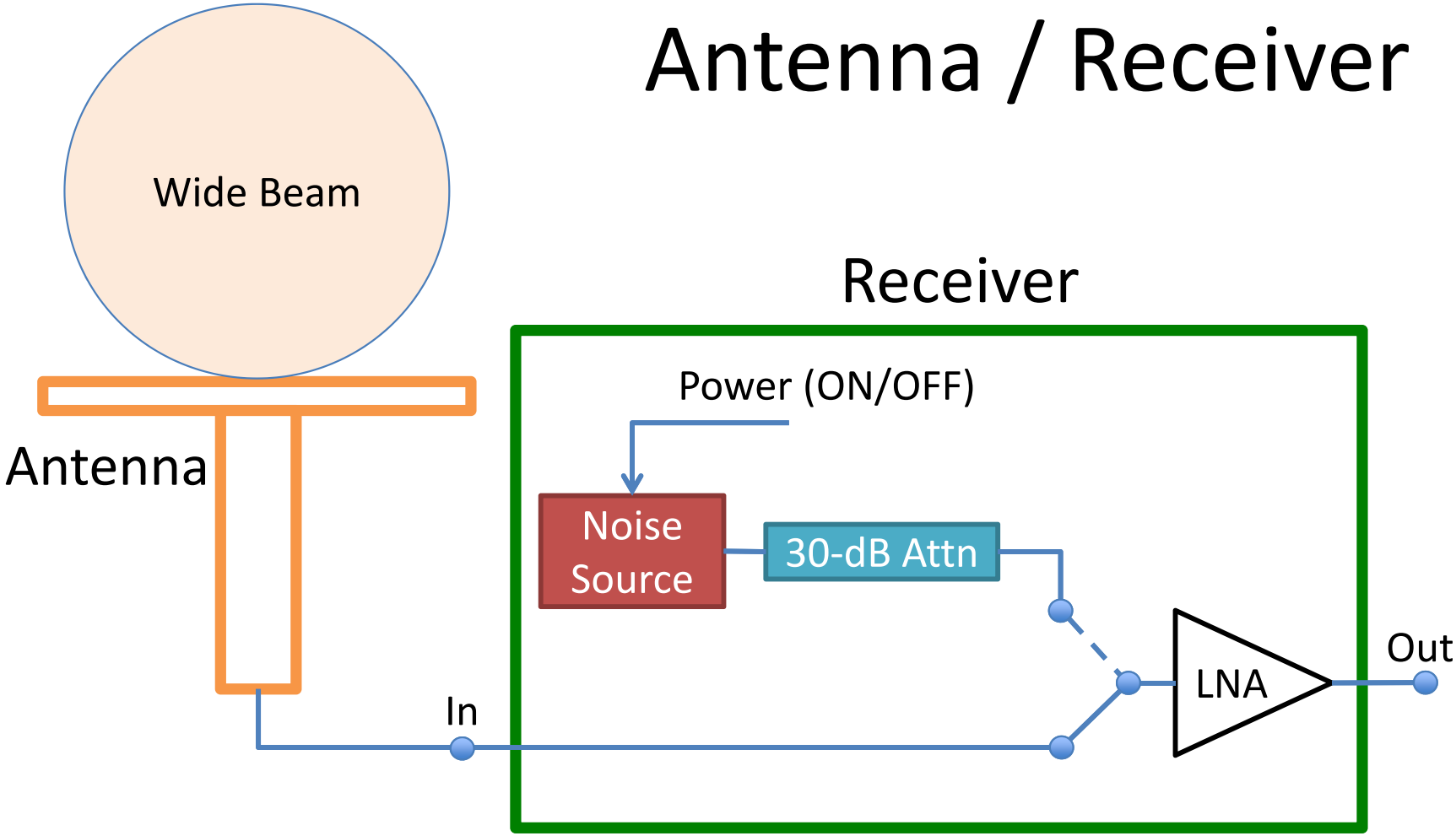
EDGES **Low-Band** 2015



EDGES **Low-Band** 2015



Antenna / Receiver



Calibration Equations

Uncalibrated Antenna Temperature:

$\boldsymbol{T^*}$: From **Internal Hot/Cold** Calibration

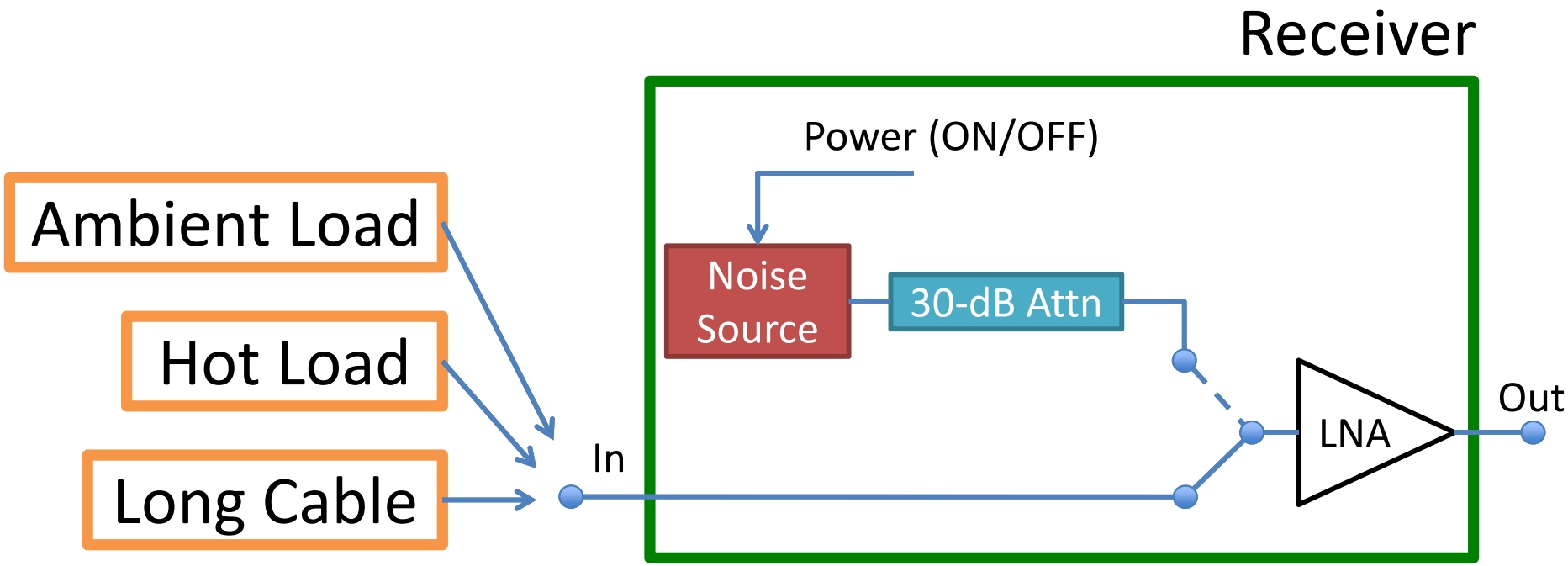
Calibrated Antenna Temperature:

$$T_{ANT} = (\boldsymbol{C_1}\,\boldsymbol{T^*} + \boldsymbol{C_2})K_B - \boldsymbol{T_U}K_U - \boldsymbol{T_C}K_C - \boldsymbol{T_S}K_S$$

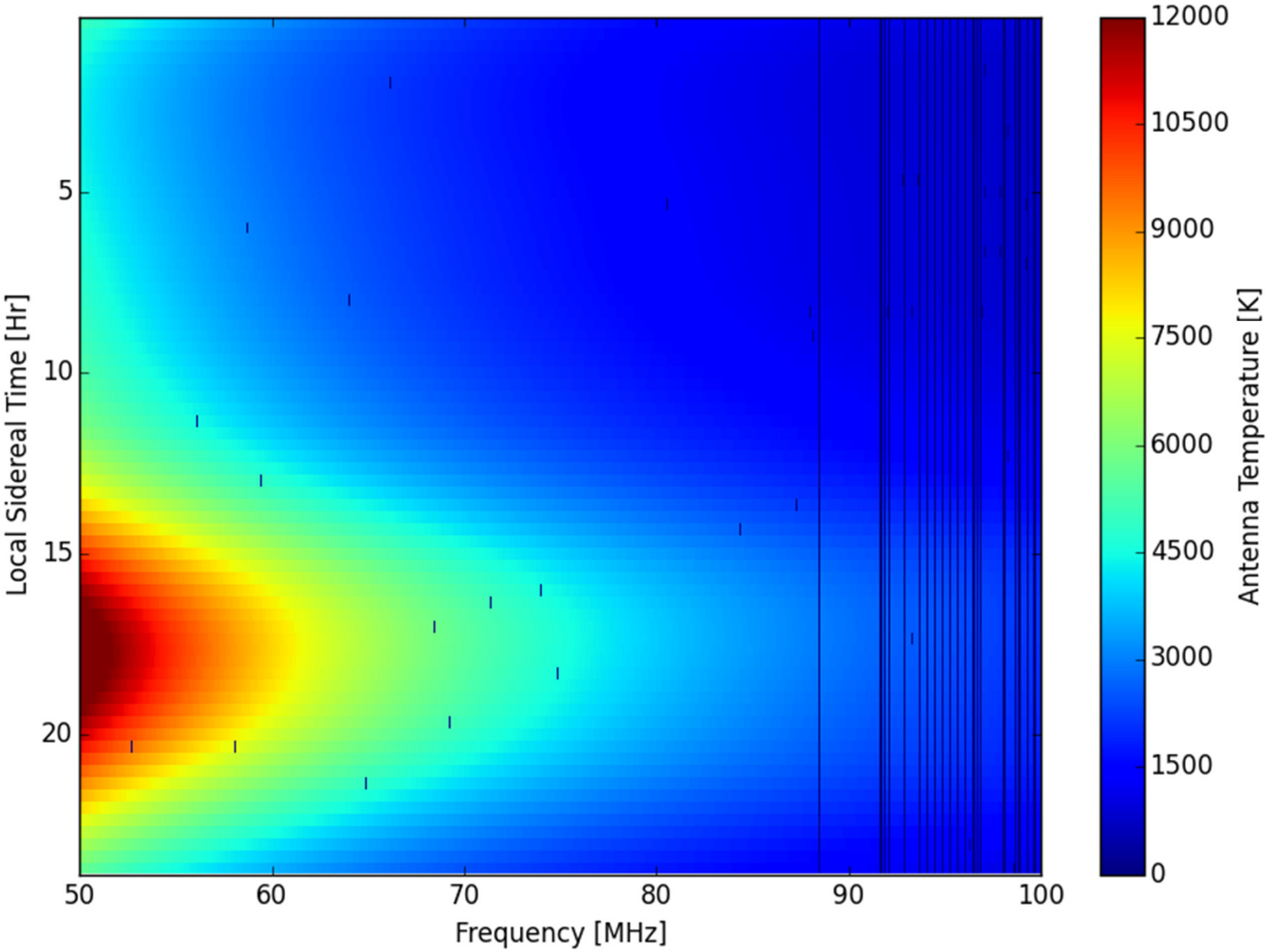
K_B, K_U, K_C, K_S Encode Reflections between Antenna and Receiver

$\boldsymbol{C_1}, \boldsymbol{C_2}, \boldsymbol{T_U}, \boldsymbol{T_C}, \boldsymbol{T_S}$ Calibration quantities obtained from Lab Measurements

Lab Calibration



24-Hr **Low-Band** Calibrated Measurement



Status of Analysis

Antenna Temperature = Cosmological Signal
+ (Antenna Beam) ⊗ (Foregrounds + Ionosphere)
+ **Antenna Losses** + **Ground Losses**
+ Calibration Systematics

One of the **efforts** on the **instrumental** side:

- Improving **modeling** and **removal** of antenna and ground **losses**.